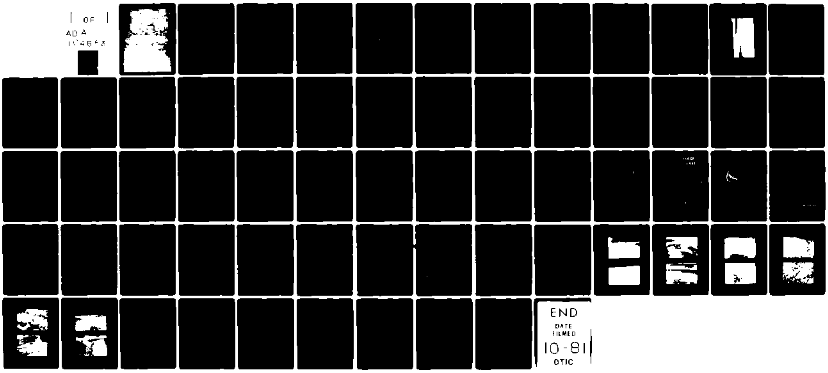
AD-A104 653 HORNER AND SHIFRIN INC ST LOUIS MO F/G 13/13
NATIONAL DAM SAFETY PROGRAM. COLE LAKE DAM (MO 30440), MISSISSI--ETC(U)
AUG 79 DACW43-79-C-0063

UNCLASSIFIED NL

1 OF 1
AD A
104653



UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A104653
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program Cole Lake Dam (MO 30440) Jefferson County, Missouri	5. TYPE OF REPORT & PERIOD COVERED 9 Final Report.
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Horner & Shifrin, Inc.	8. CONTRACT OR GRANT NUMBER(s) 15 DACW43-79-C-0063
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 11
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	12. REPORT DATE Aug[redacted]79
	13. NUMBER OF PAGES Approximately 50
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 6 National Dam Safety Program. Cole Lake Dam (MO 30440), Mississippi-Kaskaskia-St. Louis Basin, Jefferson County, Missouri. Phase I Inspection Report.	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

12 - 1

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC ELECTE SEP 28 1981 S E

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

412555

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entere

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 NORTH 12TH STREET
ST. LOUIS, MISSOURI 63101

IN REPLY REFER TO

SUBJECT: Cole Lake Dam Phase 1 Inspection Report

This report presents the results of field inspection and evaluation of the Cole Lake Dam:

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of the application of the following criteria:

1. Spillway will not pass 50 percent of the Probable Maximum Flood.

2. Overtopping of the dam and/or erosion of the spillway could result in failure of the dam.

3. Dam failure significantly increases the hazard to loss of life downstream.

SUBMITTED BY: SIGNED — 2 NOV 1979
Chief, Engineering Division — Date

APPROVED BY: SIGNED — 2 NOV 1979
Colonel, CE, District Engineer — Date

MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

COLE LAKE DAM

JEFFERSON COUNTY, MISSOURI

MO 30440

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U. S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

AUGUST 1979

COLE LAKE DAM - MISSOURI INVENTORY NO. 30440

JEFFERSON COUNTY, MISSOURI

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

HORNER & SHIFRIN, INC.
5200 OAKLAND AVENUE
ST. LOUIS, MISSOURI 63110

FOR:

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS

AUGUST 1979

HS-7925

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Cole Lake Dam
State Located:	Missouri
County Located:	Jefferson
Stream:	Tiff Creek
Date of Inspection:	19 July 1979

The Cole Lake Dam, was visually inspected by engineering personnel of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of this inspection was to assess the general condition of the dam with respect to safety and, based upon this inspection and available data, determine if the dam poses a hazard to human life or property.

The following summarizes the findings of the visual inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team. Based on the visual inspection, the present general physical condition of the dam is considered to be unsatisfactory. The following deficiencies were noticed during the inspection and are considered to have an adverse effect on the overall safety and future operation of the dam:

1. Seepage, as evidenced by soft ground and running water, was observed in the vicinity of the downstream toe of slope at the right side of the dam. Seepage was also noticed emerging from the downslope at a point above the toe of slope near the center of the dam. Uncontrolled seepage could develop into a piping condition that can lead to failure of the dam.

2. The downstream face of the dam and particularly the upper areas of the dam, have only a sparse cover of weeds to prevent erosion of the slope by storm water runoff. The emergency spillway, an earthen section, is in a similar state. All slopes and areas subject to erosion by drainage or lake outflow should be thoroughly covered by a durable form of protection.
3. Portions of the downstream side of the concrete sill at the principal spillway are severely undercut due to erosion. The downstream end of the paved chute that lies just below the concrete sill is similarly undercut by erosion. It is likely that continued erosion of the subgrade for the spillway sill could result in displacement of the sill and/or failure of the embankment supporting the chute.
4. A barbed wire type fence is located just downstream of the concrete sill for the principal spillway. The fence could act as a barrier upon which lake carried debris can lodge restricting lake outflow and resulting in flooding of the lake and possible overtopping of the dam.
5. A dense growth of small trees and brush obstructs the spillway outlet beginning at a point approximately 100 feet below the spillway crest. This growth will restrict flow in the channel that may result in flooding of the area adjacent to the downstream channel that includes the toe of the dam. Flooding of the area adjacent to the downstream side of the dam could be detrimental to the stability of the embankment.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Cole Lake Dam, which is classified as small in size and of high hazard potential, is specified to be a minimum of one-half the Probable Maximum Flood (PMF). Considering the fact that a large volume of water is impounded; the downstream floodplain is relatively narrow and flow in the stream will be deep and with high velocities; and since a county highway lies immediately below the dam and several dwellings lie within the possible flood damage zone, it is

recommended that the spillway for this dam be designed for the PMF. The *Probable Maximum Flood* (PMF) is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. Results of a hydrologic/hydraulic analysis indicated that the existing spillways are inadequate to pass lake outflow resulting from a storm of PMF magnitude. The principal spillway is adequate to pass the lake outflow resulting from the 1 percent chance (100 year frequency) flood. Both spillways, principal plus emergency, are capable of passing lake outflow corresponding to about 27 percent of the PMF lake inflow. According to the St. Louis District, Corps of Engineers, the estimated damage zone from failure of the dam extends approximately three and one-half miles downstream from the dam. Within the damage zone are County Highway E, three dwellings, and several other buildings.

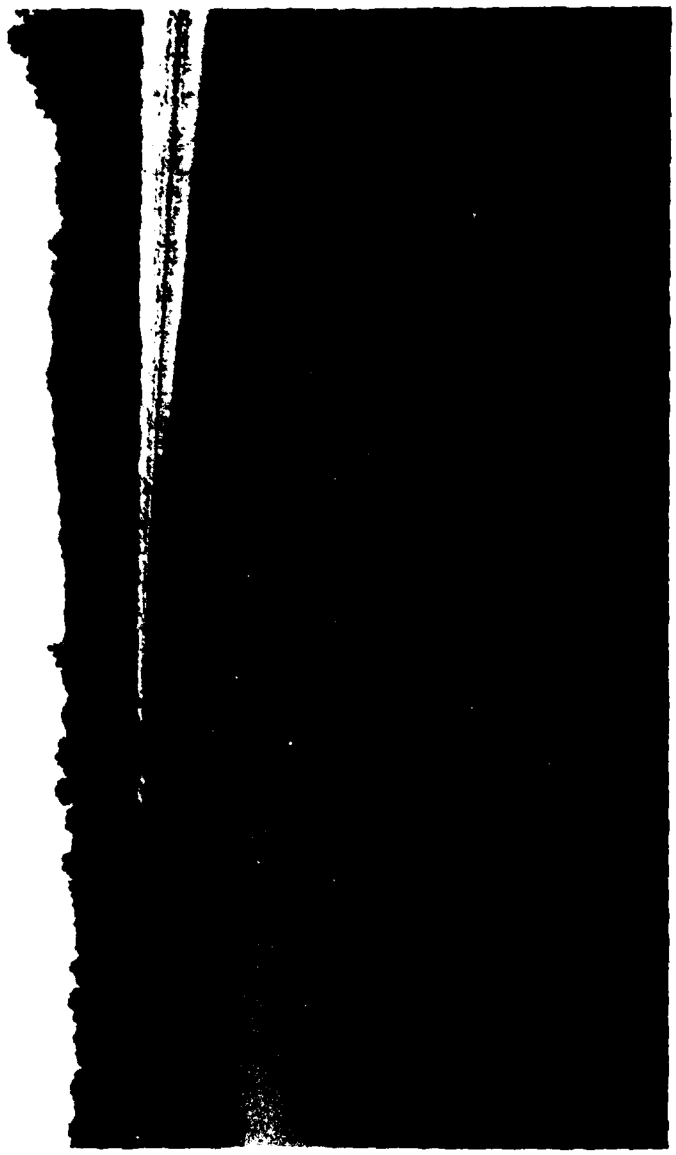
A review of available data did not disclose that seepage or stability analyses of this dam were performed. This is considered a deficiency and should be rectified. Recent additions to the dam (it was reported that in 1978, the dam was raised approximately 4 feet) have affected the structural stability of the embankment. Reportedly, the materials used to raise the dam consisted of earth (clay) and tiff gravel. It was not feasible at the time of the inspection to determine the extent to which each of the materials was used; however, judging by the appearance of the exposed materials at the top of the dam, it is believed that there is a predominance of the tiff gravel. It was also stated that the materials were hauled by truck and dumped in place and there was no effort made to regulate compaction. Further, it was observed during the visual inspection, that the downstream slope of the upper part of the dam is exceptionally steep (1v on 1.3h) which in all likelihood is a result of materials being dumped at the top of the dam and allowed to spill over the side. Therefore, because of these factors, there is concern for the structural stability of the upper part of the dam, and also for the capability of the structure, in the areas where the section consists primarily of tiff gravel, to

prevent excessive leakage during periods of higher than normal lake levels, which could result in erosion of the downstream face of the dam.

It is recommended that the Owner take the necessary action in the near future to correct or control the deficiencies and safety defects reported herein. It is advised that priority be given to performing the investigations necessary to determine the extent of all embankment materials and, utilizing this data, perform seepage and stability analyses for appropriate loading conditions, including earthquake loads.

Albert B. Becker, Jr.
P.E. Missouri E-9168

Karl L. Freese
P.E. Missouri E-16182



PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

COLE LAKE DAM - ID. NO. 30410

TABLE OF CONTENTS

Paragraph No.	Title	Page No.
	SECTION 1 - PROJECT INFORMATION	
1.1	General	1-1
1.2	Description of Project	1-1
1.3	Pertinent Data	1-1
	SECTION 2 - ENGINEERING DATA	
2.1	Design	2-1
2.2	Construction	2-1
2.3	Operation	2-1
2.4	Evaluation	2-2
	SECTION 3 - VISUAL INSPECTION	
3.1	Findings	3-1
3.2	Evaluation	3-4
	SECTION 4 - OPERATIONAL PROCEDURES	
4.1	Procedures	4-1
4.2	Maintenance of Dam	4-1
4.3	Maintenance of Outlet Operating Facilities	4-1
4.4	Description of Any Warning Systems in Effect	4-1
4.5	Evaluation	4-2

Paragraph No.	Title	Page No.
	SECTION 5 - HYDRAULIC/HYDROLOGIC	
5.1	Evaluation of Features	5-1
	SECTION 6 - STRUCTURAL STABILITY	
6.1	Evaluation of Structural Stability	6-1
	SECTION 7 - ASSESSMENT/REMEDIAL MEASURES	
7.1	Dam Assessment	7-1
7.2	Remedial Measures	7-2

LIST OF PLATES

Plate No.	Title
1	Regional Vicinity Map
2	Subdivision Plat
3	Lake Watershed Map
4	Dam Plan and Profile
5	Dam Section & Spillway Profile
6	Lake Area-Storage Curves
7	Spillway Discharge Rating Curves

APPENDIX A - INSPECTION PHOTOGRAPHS

Page No.	Title
A-1 through A-6	Inspection Photographs

APPENDIX B - HYDROLOGIC AND HYDRAULIC ANALYSES

Page No.	Title
B-1, B-2	Hydrologic & Hydraulic Computations
B-3, B-4	Computer Input Data
B-5	Summary Dam Safety Analyses
B-6	PMF Hydrographs

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

COLE LAKE DAM - ID NO. 30440

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. National Dam Inspection Act, Public Law 92-367, dated 8 August 1972.

b. Purpose of Inspection. The purpose of this visual inspection was to make an assessment of the general condition of the dam with respect to safety and, based upon available data and this inspection, determine if the dam poses a hazard to human life or property.

c. Evaluation Criteria. This evaluation was performed in accordance with the "Phase I" investigation procedures as prescribed in "Recommended Guidelines for Safety Inspection of Dams," Appendix D to "Report of the Chief of Engineers on the National Program of Dams," dated May 1975.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Cole Lake Dam is an earthfill type embankment rising 36 feet above the original streambed. The embankment has an upstream slope (above the waterline) of 1v on 1.7h, a crest width of about 12 feet, and an irregular downstream slope that varies from 1v on 1.3h at the top to 1v on 5.7h at the bottom. The length of the dam, including the spillway sections, is approximately 1,695 feet. A plan and profile of the dam are shown on Plate 4 and a cross-section of the dam is

shown on Plate 5. At normal pool elevation the reservior impounded by the dam occupies approximately 49 acres.

The principal spillway, a broad-crested trapezoidal section is located at the south or left abutment. A concrete sill section, approximately 94 feet long, serves to maintain the overflow crest. A paved concrete chute, approximately 14 feet long and 47 feet wide, lies immediately downstream of the low point of the sill. The spillway outlet channel, an unimproved trapezoidal section, abuts the chute and proceeds downstream for about 100 feet before the banks become non-existent and the channel is no longer defined. The outlet channel appears to join the downstream channel, Tiff Creek, about 600 feet below the spillway crest. A profile of the upper section of the spillway outlet channel is shown on Plate 5.

An emergency spillway, a broad-crested approximately V-shaped section, is located at the north or right abutment. The outlet channel for this spillway is also unimproved and appears to follow a course that is parallel to the toe of the dam until it joins the downstream channel, at a location about 200 feet below the dam.

b. Location. The dam is located on Tiff Creek, a tributary of Big River, about 300 feet east of County Road E and approximately 8 miles north of Bonne Terre, Missouri, as shown on the Regional Vicinity Map, Plate 1. The dam is located in Section 10, Township 38 North, Range 4 East, Jefferson County.

c. Size Classification. The size classification based on the height of the dam and storage capacity, is categorized as small. (Per Table 1, Recommended Guidelines for Safety Inspection of Dams.)

d. Hazard Classification. The Cole Lake Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that if the dam should fail, there may be loss of life, serious damage to homes, extensive agricultural, industrial and commercial facilities, important public utilities, main highways, or

railroads. According to the St. Louis District, Corps of Engineers, the estimated damage zone from failure the dam extends approximately three and one-half miles downstream from the dam. Within the damage zone are County Road E, three dwellings, and several other buildings.

e. Ownership. The lake and dam are owned by the Cole Lake Property Owners Association, Incorporated. Mr. Burford Shy is currently the Chairman of the Board of the Association. The Association's address is: Route 2, Box 232, DeSoto, Missouri - 63020.

f. Purpose of Dam. The dam impounds water for recreational use by property owners who are members of the association.

g. Design and Construction History. According to Mr. Burford Shy, the dam was constructed in 1947 by his brother, Paul N. Shy, a contractor experienced in the construction of earthen dams. According to information shown on the Coles Lake Subdivision Plat, dated December 9, 1948, see Plate 2, the original owners of the property upon which the dam and lake are founded, were John Cole and his wife, Bernice Cole, and Paul N. Shy, the builder of the dam. The present Owners, the Cole Lake Property Owners Association, Inc., acquired control of the dam, lake, and other common ground within the subdivision in 1974. According to Mr. Shy, the dam was constructed without the benefit of formal engineering design data or plans.

Mr. Shy also reported that in 1978, several improvements were made to the dam by the property owner's association. These improvements consisted of raising the dam approximately 4 feet, widening the principal spillway, raising the crest of the emergency spillway, removing trees from the upstream and downstream faces of the dam, and installing riprap across a portion of the upstream face of the dam.

h. Normal Operational Procedure. The lake level is unregulated.

1.3 PERTINENT DATA

a. Drainage Area. The area tributary to the lake is essentially undeveloped, partially in pasture with the remainder in a native state covered with timber. The area adjacent to the lake has been subdivided and there are numerous homes and other buildings about the lake. The watershed above the dam amounts to approximately 774 acres. The watershed area is outlined on Plate 3.

b. Discharge at Damsite.

(1) Estimated known maximum flood at damsite ... 370 cfs* (W.S. Elev. 824.5)

(2) Spillway capacity (principal) ... 690 cfs (W.S. Elev. 825.1)

(3) Spillway capacity (principal + emergency) ... 1,780 cfs (W.S. Elev. 826.4)

c. Elevation (ft. above MSL). The low point of the concrete sill at the principal spillway crest was assumed to be elevation 823.0; the basis for this assumption being the elevation of the lake surface shown on the 1960 Vineland, Missouri Quadrangle Map, 7.5 minute series.

(1) Top of dam ... 826.4 (min.)

(2) Normal pool (spillway crest) ... 823.0

(3) Streambed at centerline of dam ... 792±

(4) Maximum tailwater ... Unknown

d. Reservoir.

(1) Length at normal pool (elevation 823.0) ... 2,500 ft.

(2) Length at maximum pool (elevation 826.4) ... 2,700 ft.

e. Storage.

(1) Normal pool ... 476 ac. ft.

(2) Top of dam (incremental) ... 172 ac. ft.

*Based on a high water mark as observed by a representative of the Owner.

f. Reservoir.

(1) Top of dam ... 52 acres

(2) Normal pool ... 49 acres

f. Dam.

(1) Type ... Earthfill, homogeneous*

(2) Length ... 1,695 ft.

(3) Height ... 36 ft.

(4) Top width ... 12 ft.

(5) Side slopes

a. Upstream ... 1v on 1.7h (above waterline)

b. Downstream ... Irregular, 1v on 1.3h to 1v on 5.7h

(6) Cutoff ... Clay core*

(7) Slope protection

a. Upstream ... Riprap (partial), tiff gravel

b. Downstream ... Weeds and brush

h. Principal Spillway.

(1) Type ... Uncontrolled, concrete sill, trapezoidal section

(2) Location ... Left abutment

(3) Length ... 94 ft.

(4) Crest ... Elevation 823.0

(5) Approach channel ... Lake

(6) Exit channel ... Earth cut, trapezoidal section

i. Emergency Spillway.

(1) Type ... Uncontrolled, earth, V-section

(2) Location ... Right abutment

(3) Crest ... Elevation 825.1

(4) Approach channel ... Lake

(5) Exit channel ... Unimproved

j. Lake Drawdown Facility. None

*Per a representative of the Owner

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No engineering data relating to the design of the dam are known to exist.

2.2 CONSTRUCTION

The following information was obtained from Mr. Burford Shy, present Chairman of the Board for the lake property owners' association. Mr. Shy worked for his brother, Paul, during the period (1947) when the Cole Lake Dam was being constructed:

> "The dam was constructed with clay obtained from the area to be occupied by the lake. Two bulldozers and three tractor drawn scrapers were used to move and place the fill material for the dam. A core trench, to an estimated maximum depth of about 15 feet, was excavated to rock along the centerline of the dam and backfilled with clay. Layers of gravel were encountered at the streamline while excavating the core trench. Compaction of the fill and backfill was achieved by running the earth hauling equipment over the previously placed fill layer. No compaction tests were made or records kept of the dam construction work."

Mr. Shy also stated that springs were encountered during construction of the dam at the approximate locations that seepage was observed during the inspection.

2.3 OPERATION

The lake level is uncontrolled and governed by the crest elevation of the principal spillway located at the left abutment. An emergency spillway, with a crest elevation approximately 2.1 feet higher than the crest of the principal spillway and about 1.3 feet

lower than the top of the dam at its lowest point, is located at the right abutment. A representative of the Owner, reported that the highest lake level observed occurred during the sping of 1979 (the dam was raised in 1978) and, judging by a high water mark, was estimated to be approximately 18 inches above the normal pool level. It was also stated that the dam, prior to being raised had not been overtopped.

2.4 EVALUATION

Avalability. Engineering data for assessing the design of the dam and spillways were unavailable.

b. Adequacy. No data available. Seepage and stability analyses comparable to the requirements of the 'Recommended Guidelines for Safety" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General A visual inspection of the Cole Lake Dam was made by Horner & Shifrin engineering personnel, T.K. Deddens, Geological Engineer, K.L. Freese, Civil Engineer and Hydrologist, and A.B. Becker, Jr., Civil and Soils Engineer, on 19 July 1979. An examination of the dam site was also made by an engineering geologist, Jerry D. Higgins, a consultant retained by Horner & Shifrin for the purpose of assessing the area geology. Also examined at the time of the inspection, was the area below the dam within the potential flood damage zone. Photographs of the dam taken at the time of the inspection are included on Pages A-1 through A-6 of Appendix A. The location of and direction in which the inspection photographs were taken is indicated on Plate 4.

b. Area Geology. The dam site is located on the northern flank of the Ozark Uplift on nearly flat-lying Cambrian age sedimentary rock. The uniform bedrock structure is intersected by the northwest-southeast trending Valles Mine-Vineland Fault which passes through the area approximately 3 miles north of the dam site. In the general area the Cambrian age Potosi formation is exposed at the surface. The Potosi formation is a massive, thickly-bedded, medium-to-fine-grained dolomite with abundant quartz druse and chert. The hilltops in the area are reported to be capped by cherty dolomite of the Eminence formations.

The dam and reservoir are founded on gently sloping Potosi residuum. The residuum, derived from insitu weathering, is a blocky, red clay with abundant quartz druse and chert. There has been no severe erosion of residuum around the lake, although erosion has occurred in the emergency spillway outlet channel. Both abutments are composed of gently sloping Potosi residuum with bedrock exposures limited to the spillway at the left abutment. The abutment slopes appear stable with no severe erosion evident.

The Valles Mines-Vineland Fault, which does not cross the dam site, is considered to be an extension of the St. Genevieve Fault system and a part of the St. Genevieve Seismotectonic Region. This Seismotectonic Region has been the center of several significant historic seismic events. An event of Modified Mercalli Intensity of VII may occur in this region based upon the postulated recurrence of historic earthquake events. Based upon the site geology and distance from the fault system, the most likely seismic hazard would be the result of induced ground motion rather than ground failure by faulting.

c. Dam. The visible portions of the upstream and downstream faces of the dam (see Photos 1 and 2) appeared to be in sound (no cracks or slides were noticed) condition, although the upper areas of the embankment slopes are exceptionally steep. The material exposed at the dam crest and upstream face of the dam, except for riprapped areas and spotty patches of weeds, consisted of tiff gravel, a small stone that ranges in size up to about 3/4 of an inch. The riprap, a stone about 4 inches across in size, covered approximately 60 percent of the upstream face of the dam (see Photo 12) and extended from below the waterline to near the top of the dam. Only a sparse growth of weeds (see Photo 7) existed on the upper areas of the downstream face of the dam, while the lower areas were densely covered with weeds and brush. Felled trees were also present at several locations along the downstream toe of the dam. A ridge approximately 2 feet high was observed in the lake, about 1 foot below the surface, paralleling the dam at a location approximately 8 feet from the face of the dam. The ridge extended from a point beginning near the principal spillway for a distance of approximately 500 feet. The reason for the ridge was not apparent.

At a location near the center of the dam and a point about 20 feet below the crest, seepage estimated to be flowing at a rate of about 1 gpm, was observed emerging from the face (see Photo 8) of the dam. Seepage was also noticed emerging from the base of the dam (see Photo 9) at a location approximately 150 feet from the right abutment. The exact location of the point of exit for this seepage

could not be determined. However, the flow was estimated to be about 2 gpm. The area adjacent to and paralleling the right side of the dam (see Photo 10) was soft with seepage flowing in a shallow erosion channel just below the toe of the slope. There was also evidence of surface erosion, a gully was cut up to 12 inches in depth, that appeared to be due to storm water runoff, through this same area.

The subgrade at the downstream side of the 4-inch thick concrete sill at the principal spillway was found to be partially eroded (see Photo 4) across half of the section. Undercutting of the sill extended to a depth of up to one foot in several locations. Due to lack of support, several sections of sill slab were broken, leaving the downstream side in a ragged condition. The subgrade at the downstream end of the paved chute (see Photo 5) that lies below the spillway sill was also eroded across almost the entire section. Undercutting of the paved surface, a free-formed section, extended to a depth of up to 2.5 feet with over 12 inches of subgrade material missing. Some seepage, estimated to be on the order of 1 gpm, was observed flowing from the exposed subgrade at the end of the chute. A three-strand barbed-wire type fence, located adjacent to the downstream side of the spillway sill was found to extend across the entire spillway. The spillway outlet channel below the chute, although unimproved, (see Photo 6) was found to be in fair condition with few obstructions and only minor erosion of the section. However, beginning at a point approximately 100 feet below the spillway crest, the channel was found to be overgrown with small trees and brush. The channel, through the low lying area below the dam and east of County Road E, was found to be densly covered with brush, cattails, trees, and other vegetation.

The crest of the emergency spillway (see Photo 11) was found to be in sound condition, although some minor surface erosion due to storm water runoff was noticed. The crest as well as the upstream and downstream faces of the spillway channel, with the exception of some weed growth, had no protective covering to prevent erosion.

The outlet channel for this spillway was also found to lack protective covering, with erosion up to 12 inches in several places, having occurred through the drainage area.

Although no animal burrows were noticed at the time of the inspection, it was reported that during the previous year (1973), approximately 105 muskrats were taken from the dam area.

d. Downstream Channel. The channel downstream of the dam, Tiff Creek, is unimproved and extends for approximately 4 miles before joining the Big River.

At a distance of about 300 feet below the dam, a 12-foot wide by 7-foot high concrete box culvert allows stream flow to cross County Road E. At the time of the inspection, flow in the culvert was estimated to be about 4 to 5 gpm, approximately the same quantity of flow observed, and believed to be seepage from the lake.

e. Reservoir. Numerous homes and other buildings are present in the area adjacent to the lake. The lake shoreline is grass covered and tree lined and appeared to be well maintained. The very upstream end of the lake is crossed by a county road where a concrete box culvert allows flow to pass beneath the road. The amount of sediment within the lake could not be determined at the time of the inspection. However, a representative of the Owner reported that when constructed, the lake at its deepest point was about 55 feet deep, but now is believed to be only 45 feet deep at its deepest location.

3.2 EVALUATION

With the exception of the steep upstream and downstream slopes that exist near the top of them, the deficiencies observed during this inspection and noted herein, are not considered significant to wararant immediate remedial action.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The spillways are uncontrolled. The water surface level is governed by precipitation runoff, evaporation, seepage, and the capacity of the uncontrolled principal and emergency spillways.

4.2 MAINTENANCE OF DAM

As previously indicated, improvements have recently (1978) been made to the dam and spillways. According to a representative of the Owner, with the exception of the riprap placed on the upstream face of the dam, these improvements are complete. However, based on the extensive growth of weeds and brush that exist on the dam and elsewhere as well as the lack of a perennial plant cover to prevent erosion, it would appear that these areas are in need of additional maintenance. Further, it also appears that little has been done to prevent occurrence of problems associated with seepage including drainage of the low lying areas, where the water accumulates near the base of the dam.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

No outlet operating facilities exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEMS IN EFFECT

The inspection did not reveal the existence of a dam warning system.

4.5 EVALUATION

Lack of or inadequate maintenance is considered detrimental to the safety of the dam. It is recommended that maintenance of the dam and spillways be undertaken on a regular basis and that records be kept of all maintenance work performed.

SECTION 5 - HYDROLOGIC/HYDRAULIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data are not available.

b. Experience Data. The drainage area and lake surface area were developed from the USGS Vineland, Missouri, Quadrangle Map. The proportions and dimensions of the spillways and dam were developed from surveys made during the inspection.

c. Visual Observations.

(1) The principal spillway crest consists of a 94-foot long concrete sill of variable width. A concrete chute lays immediately below the south half of the spillway sill. The subgrade for the north half of the sill as well as the subgrade at the downstream end of the chute, are extensively eroded with both sections undercut. A three strand barbed-wire fence, supported by metal posts embedded in the sill, crosses the spillway opening.

(2) The principal spillway is located within the embankment near the left (south) abutment.

(3) Below the spillway sill and concrete chute, the outlet channel consists of a trapezoidal-shaped section approximately 8 feet wide and 3 to 4 feet deep, that continues for about 100 feet before joining a draw of the original drainage pattern. The draw follows a course away from the downstream face of the dam. The jagged surface of the Potosi formation is exposed in the invert of the upper reach of the channel. The lower portion of the reach is congested with small trees and brush.

(4) The downstream face near the top of the dam is exceptionally (1v on 1.3h) steep. The upstream face above the waterline is also steep. Judging by the type of material exposed to view, this upper portion consists primarily of tiff gravel. In addition, this portion of the embankment does not have perennial type plant cover to prevent erosion by storm water runoff. The

lower portions of the embankment appear to consist of native soil, a red, gravelly clay.

(5) The emergency spillway consists of a shallow, dish-shaped depression through the dam near the right (north) abutment. The spillway discharges into a natural draw that conveys water away from the dam by following a course that roughly parallels the base of the dam.

(6) No drawdown facilities are available to dewater the lake.

d. Overtopping Potential. Elevation 826.4 was found to be lowest point in the dam crest. The spillways (principal and emergency) are inadequate to pass the probable maximum flood or the 1/2 probable maximum flood without overtopping the dam. They are adequate, however, to pass the 1 percent chance (100-year frequency) flood without overtopping the dam. The results of a dam overtopping analysis are as follows:

Ratio of PMF	Q-Peak Outflow (cfs)	Max. Lake W.S. Elev.	Maximum Depth of Flow Over Dam (Ft.) (Elev. 826.4)	Duration of Overtopping Of Dam (Hours)
0.27	1,780	826.4	0.0	0.0
0.50	4,668	827.5	1.1	1.6
1.00	11,043	828.3	1.9	5.0
100-Yr. Flood	1,065	825.6	0.0	0.0

The flow safely passing the spillways just prior to overtopping, was determined to be 1,780 cfs, which amounts to approximately 27 percent of the probable maximum flood inflow. This outflow is greater than the outflow for the 1 percent chance (100-year frequency) flood. During peak flow of the probable maximum flood, the greatest depth of flow over the dam would be approximately 1.9 feet and the overflow will extend for about the entire length of the dam crest.

e. Evaluation. Based on the erosion that has occurred at the principal spillway (the concrete sill and chute are extensively undercut) it is evident that the embankment material, a gravelly red clay, can under certain circumstances, such as large spillway releases with accompanying high velocities, be very erodible. Also, during flood conditions when flow over the dam occurs, it is expected that rapid erosion of the unprotected steep downstream slopes that are composed at least in part of tiff gravel, will occur. Therefore, for lake flooding conditions that result in flow over the top of the dam, failure of the dam is expected.

f. References. Procedures and data for determining the probable maximum flood, the 100-year frequency flood, and the discharge rating curve for flow passing the spillways and the dam crest are presented on Pages B-1 and B-2 of the Appendix. A listing of the HEC-1 (Dam Safety Version) input data for routing the probable maximum flood and the 1 percent chance (100-year frequency) flood is shown on Pages B-3 and B-4 of the Appendix. A copy of the computer output table entitled "Summary of Dam Safety Analysis" is presented on Page B-5 and the inflow and outflow hydrographs for the probable maximum flood are shown on Page B-6 of the Appendix. Area-storage curves for the reservoir are presented on Plate 6 and the spillway discharge rating curves are shown on Plate 7.

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. An item noticed during the inspection and considered to be of significant importance to the performance of the dam, is the exceptionally steep slopes that exist on the upstream and downstream faces of the embankment. The inspection also revealed that materials used to raise the dam (see paragraph 6.1d) consisted of an undeterminable combination of tiff gravel and clay. Other items noticed during the inspection include seepage, lack of perennial plant cover in certain areas subject to erosion by storm water runoff or spillway flow, and dense brush that could conceal animal burrows. The location and extent of these items is discussed in Section 3, paragraph 3.1c .

b. Design and Construction Data. No construction data relating to the structural stability of the dam are known to exist. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Operating Records. No appurtenant structures or facilities requiring operation exist at this dam. According to a representative of the Owner, no records are kept of the lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. Based on information provided by a representative of the Owner, it is believed that there have been several changes to the dam since completion of construction in 1947 that could have an affect on the structural stability of the dam. These changes, all of which were reported to have been implemented in 1978, include raising the dam approximately 4 feet, increasing

the width of the principal spillway opening from about 47 feet to approximately 94 feet, and raising the crest of the emergency spillway approximately 1 foot.

e. Seismic Stability. Based on the steep downstream slope in the upper regions of the dam, the lack of stability analyses as well as knowledge of materials used and methods employed to raise the dam, a judgment as to the effect of an earthquake on this dam cannot be made at this time. However, a geologic fault is relatively close (approximately 3 miles) to the damsite and the use of tiff gravel for dam construction is of questionable value. A quake at the damsite could cause the relatively loose tiff gravel to become unstable, resulting in slope failure at the top of the dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. A hydraulic analysis indicates the spillways (principal plus emergency) are capable of passing lake outflow of about 1,780 cfs without the level of the lake exceeding the low point in the top of the dam. A hydrologic analysis of the lake watershed area, as discussed in Section 5, paragraph 5.1d, indicated that for storm runoff of probable maximum flood magnitude, the lake outflow would be on the order of 11,043 cfs, and that for the 1 percent chance (100-year frequency) flood, the lake outflow would be about 1,065 cfs.

Several items were noticed during the inspection that could adversely affect the safety of the dam. These items include the exceptionally steep slopes that exist at the upstream and particularly the downstream faces of the dam, seepage, lack of perennial plant cover in areas subject to erosion by storm water runoff and/or lake outflow, dense brush in certain areas that may conceal animal burrows, and a barbed-wire type fence that traverses the crest of the principal spillway.

Stability and seepage analyses of the dam were not available for review and therefore no judgment could be made with respect to the structural stability of the dam. Due to the fact that the upper areas of the dam have slopes that are unusually steep, it is questionable if the stability of the embankment is adequate for all service conditions.

b. Adequacy of Information. Due to lack of design and construction data, the assessments reported herein were based on external conditions as determined during the visual inspection. The assessment of the hydrology of the watershed and capacities of the spillways were based on a hydrologic/hydraulic study as indicated in Section 5. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of

Dams" were not available, which is considered a deficiency.

c. Urgency. The items concerning the safety of the dam noted in Paragraph 7.1a and the remedial measures recommended in Paragraph 7.2 should be accomplished in the near future.

d. Necessity for Phase II. Based on the results of the Phase I inspection, a Phase II investigation is not recommended.

e. Seismic Stability. Based on the steep downstream slopes in the upper regions of the dam and the lack of stability analyses as well as knowledge of materials used and methods employed to raise the dam, a judgment as to the effect of an earthquake on this dam cannot be made at this time. However, a geologic fault is relatively close (approximately 3 miles) to the damsite and the use of tiff gravel for dam construction is of questionable value. A quake at the damsite could cause the relatively loose tiff gravel to become unstable, resulting in slope failure at the top of the dam.

7.2 REMEDIAL MEASURES

a. Recommendations. The following actions are recommended:

(1) Based upon criteria set forth in the recommended guidelines, alterations to the design of the dam should be made in order to pass lake outflow resulting from a storm of probable maximum flood magnitude.

(2) Obtain the necessary soil data and perform dam stability and seepage analyses in order to determine the structural stability of the dam for all operational conditions. Seepage and stability analyses should be performed by a qualified professional engineer experienced in the design and construction of dams that include the use of tiff material for embankment fill.

b. <u>Operations and Maintenance (O & M) Procedures.</u> The following O & M Procedures are recommended:

(1) Remove the trees as well as the fallen trees and brush, that may conceal animal burrows, from the downstream face of the dam and the area adjacent to the downstream toe of the slope. Holes from tree roots and voids created by burrowing animals provide a pathway for seepage that can lead to a piping (progressive internal erosion) condition and potential failure of the dam. The existing turf cover should be restored if destroyed or missing (much of the downstream face has no perennial type of plant cover). Maintain the turf cover on the slopes at a height that will not hinder inspection of the slope or provide cover for burrowing animals. The removal of trees should be performed under the guidance of an engineer experienced in the design and construction of earth dams, since indiscriminate clearing can jeopardize the safety of the dam.

(2) Provide some means of preventing piping due to seepage at the downstream face of the dam. A piping condition can result in failure of the dam.

(3) Drain the low lying areas adjacent to the toe of the dam in order to prevent soft ground and conditions detrimental to the stability of the embankment.

(4) Remove the trees and brush from the downstream area of the principal spillway outlet channel in order to allow flow to reach the downstream channel unrestricted. Restricting flow in the spillway channel can result in flooding of the area adjacent to the downstream toe of the dam and conditions unfavorable to the stability of the embankment.

(5) Remove the barbed-wire type fence that traverses the crest of the principal spillway and provides a barrier on which lake carried debris could lodge, resulting in a

restriction of the spillway opening and unwarranted flooding of the lake and possibly overtopping of the embankment.

(6) Restore the subgrade at the downstream ends of the concrete sill and paved chute at the principal spillway and provide some means of preventing future erosion at these locations. Loss of subgrade could result in settlement of the sill (crest) or instability of the dam at this location, since loss of materials below the chute will affect the stability of the section.

(7) The benefit of riprap to prevent erosion of the upstream face of the dam in the case where the embankment material consists of tiff gravel is questionable. However, if riprap is considered desireable, it is recommended that selection of riprap be done by a qualified soils engineer in order to insure proper gradation and size. Riprap is necessary to prevent erosion of an earth embankment by wave action.

(8) A detailed inspection of the dam should be instituted on a regular basis by an engineer experienced in the design and construction of dams. It is also recommended, for future reference, that records be kept of all inspections made and remedial measures taken.

(9) Provide maintenance of all areas of the dam and spillways on a regularly scheduled basis in order to insure features of being in satisfactory operational condition.

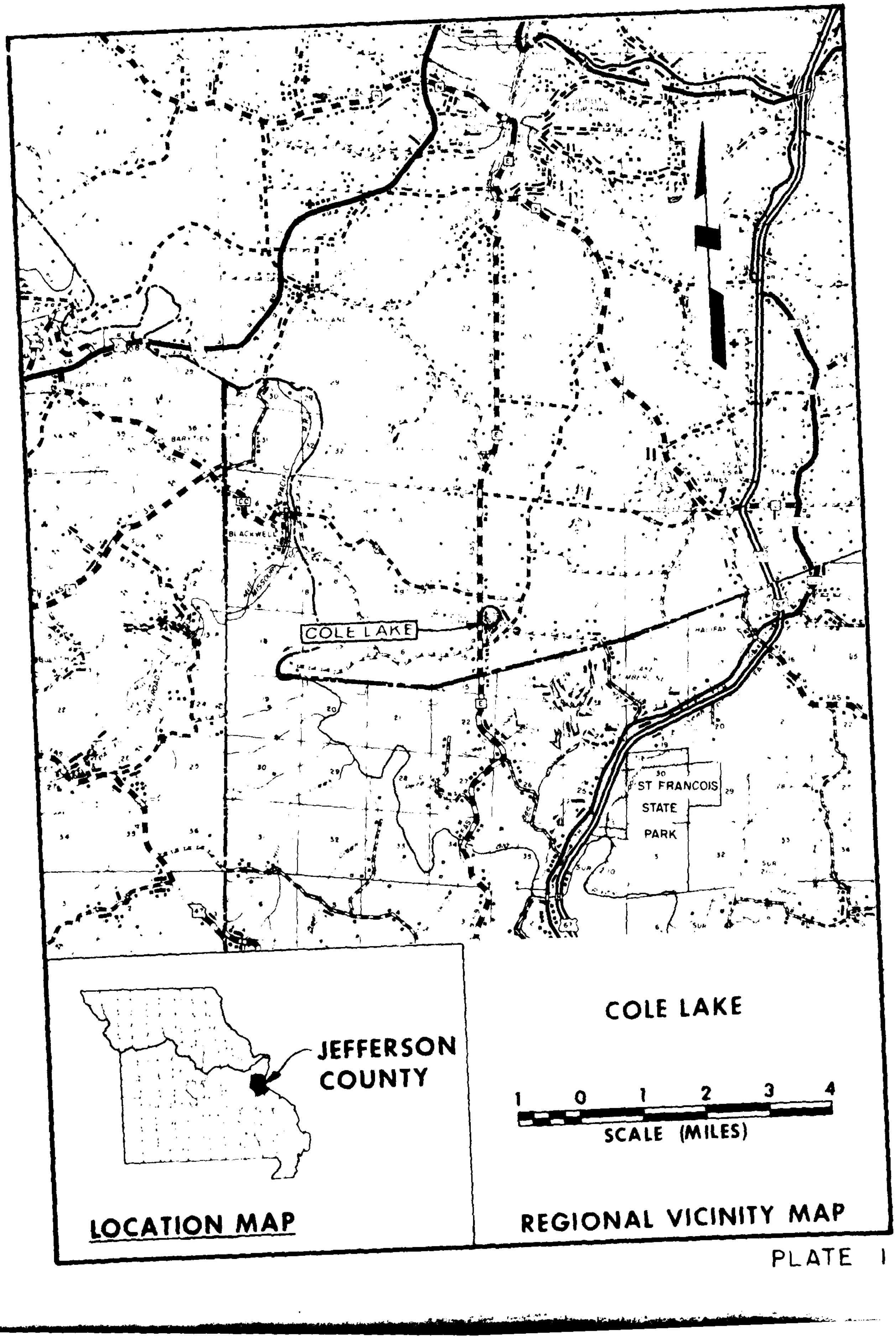

COLE LAKE
ST FRANCOIS
STATE
PARK
BLACKWELL
HALIFAX
JEFFERSON
COUNTY
LOCATION MAP
COLE LAKE
1 0 1 2 3 4
SCALE (MILES)
REGIONAL VICINITY MAP

PLATE 1

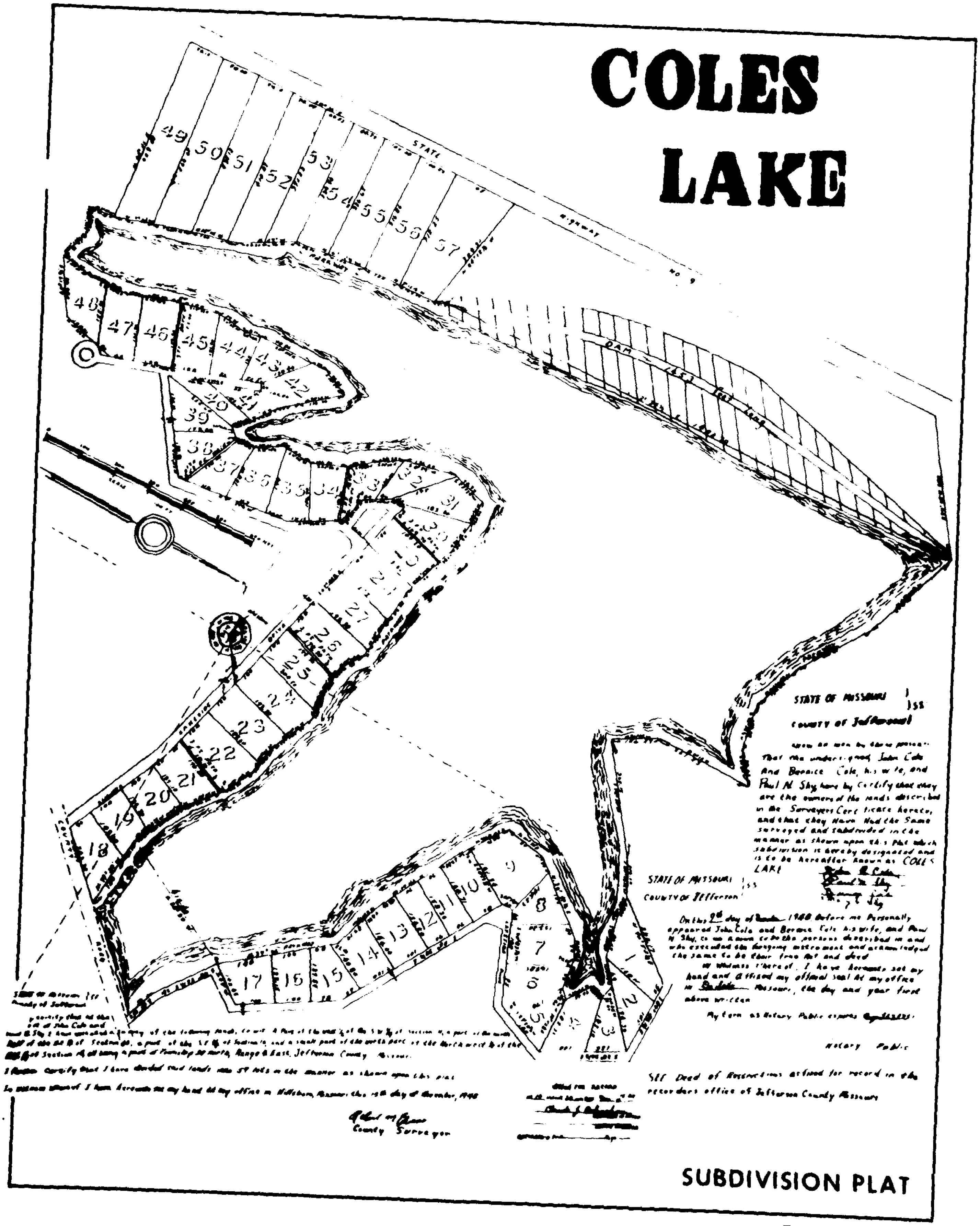
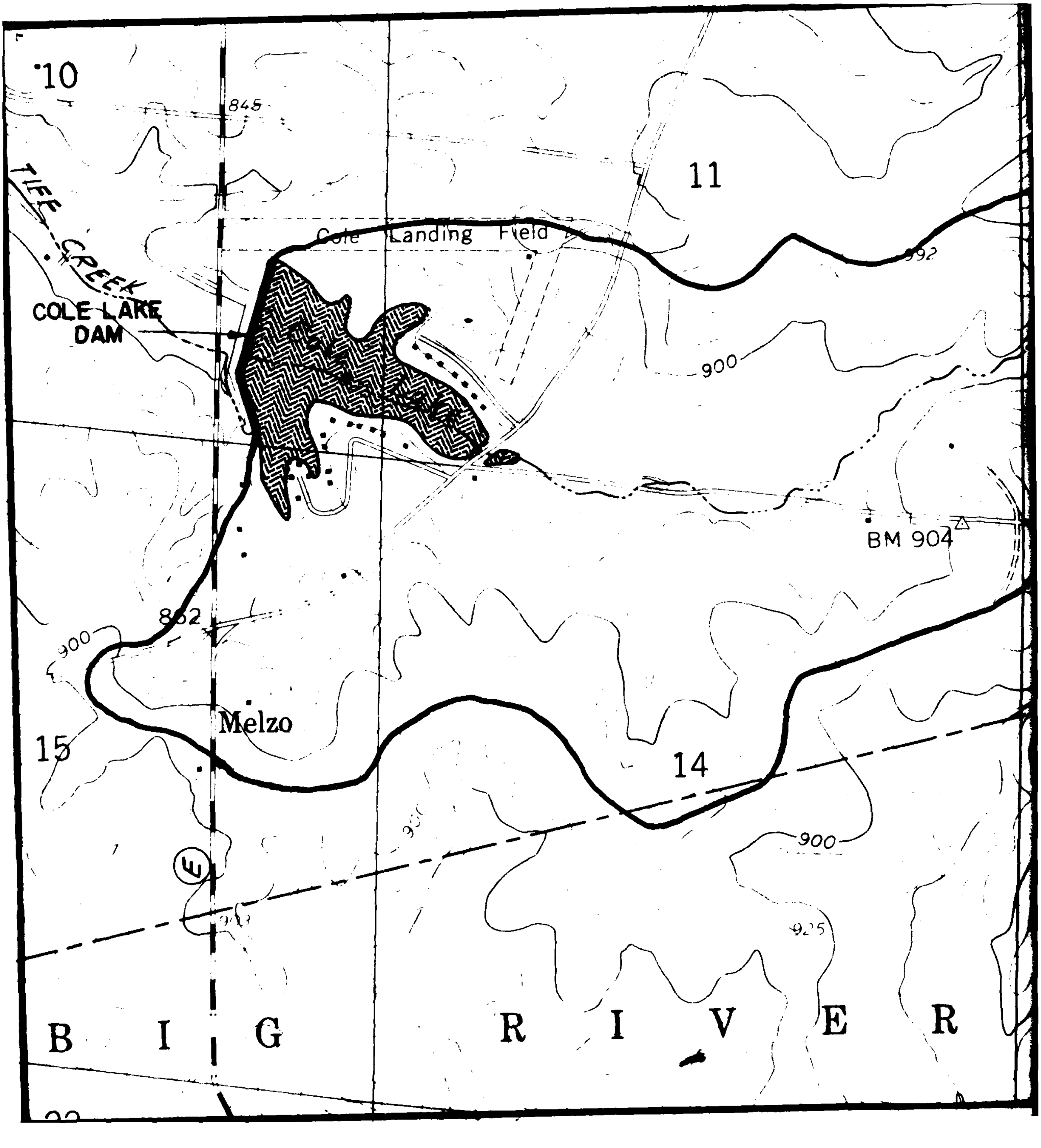
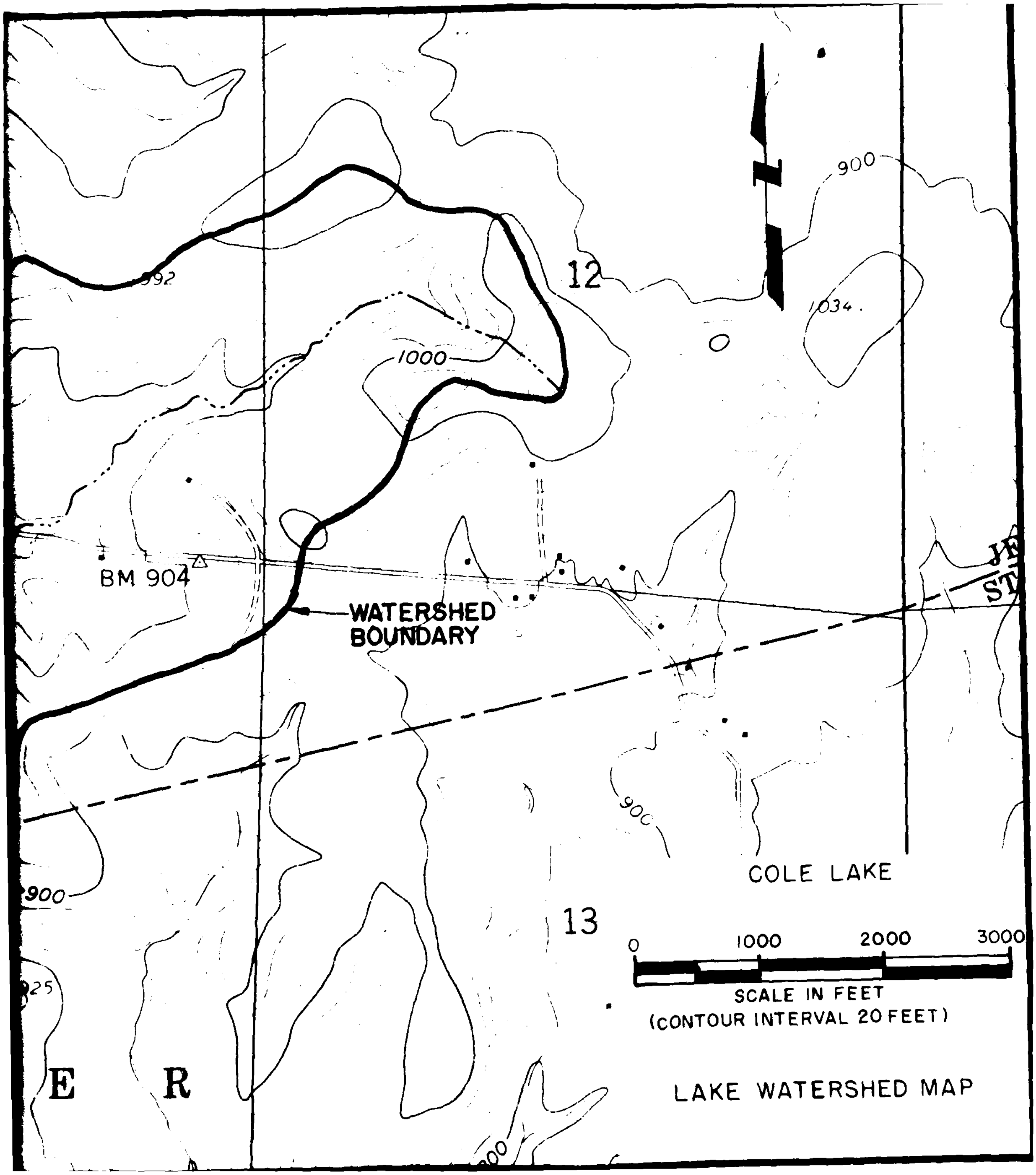
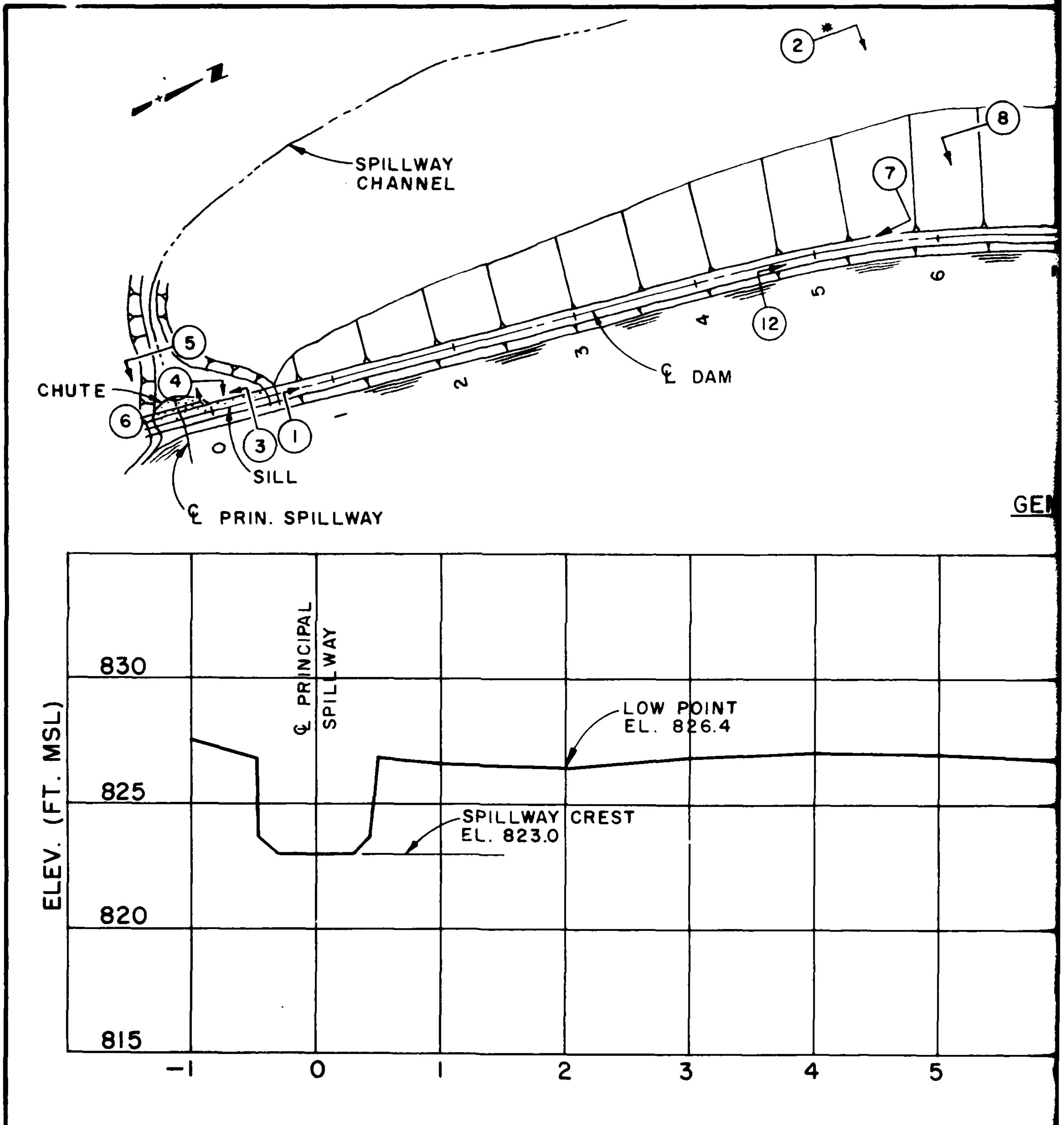


PLATE 2


10
848
11
TIFF CREEK
Cole Landing Field
992
COLE LAKE
DAM
900
BM 904
862
900
Melzo
15
14
900
925
E
B I G R I V E R



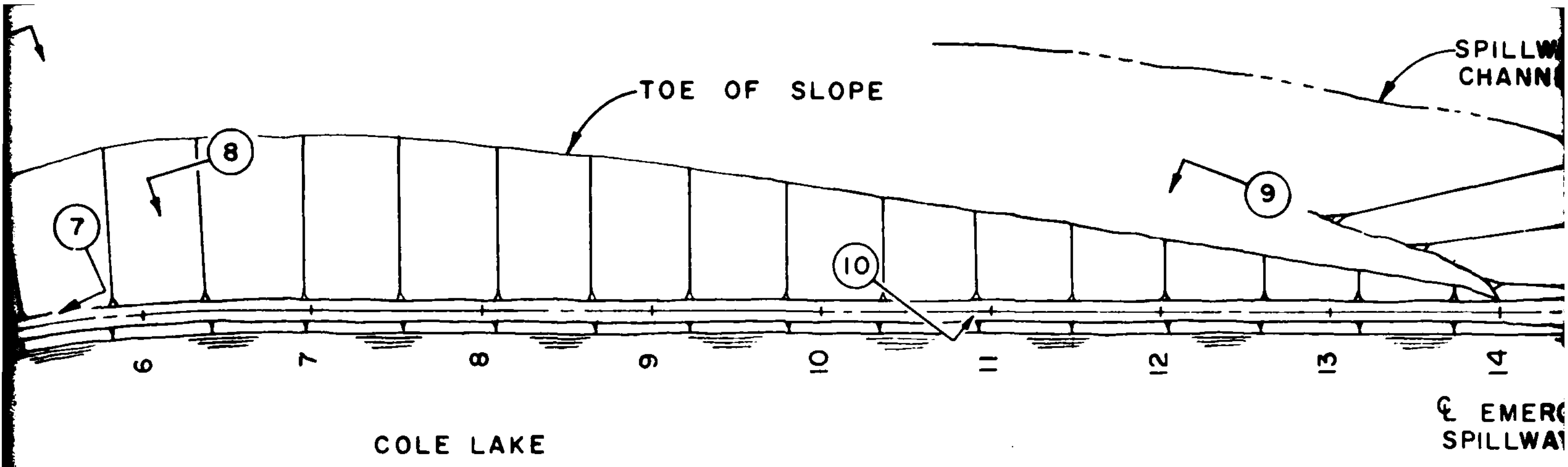
LAKE WATERSHED MAP



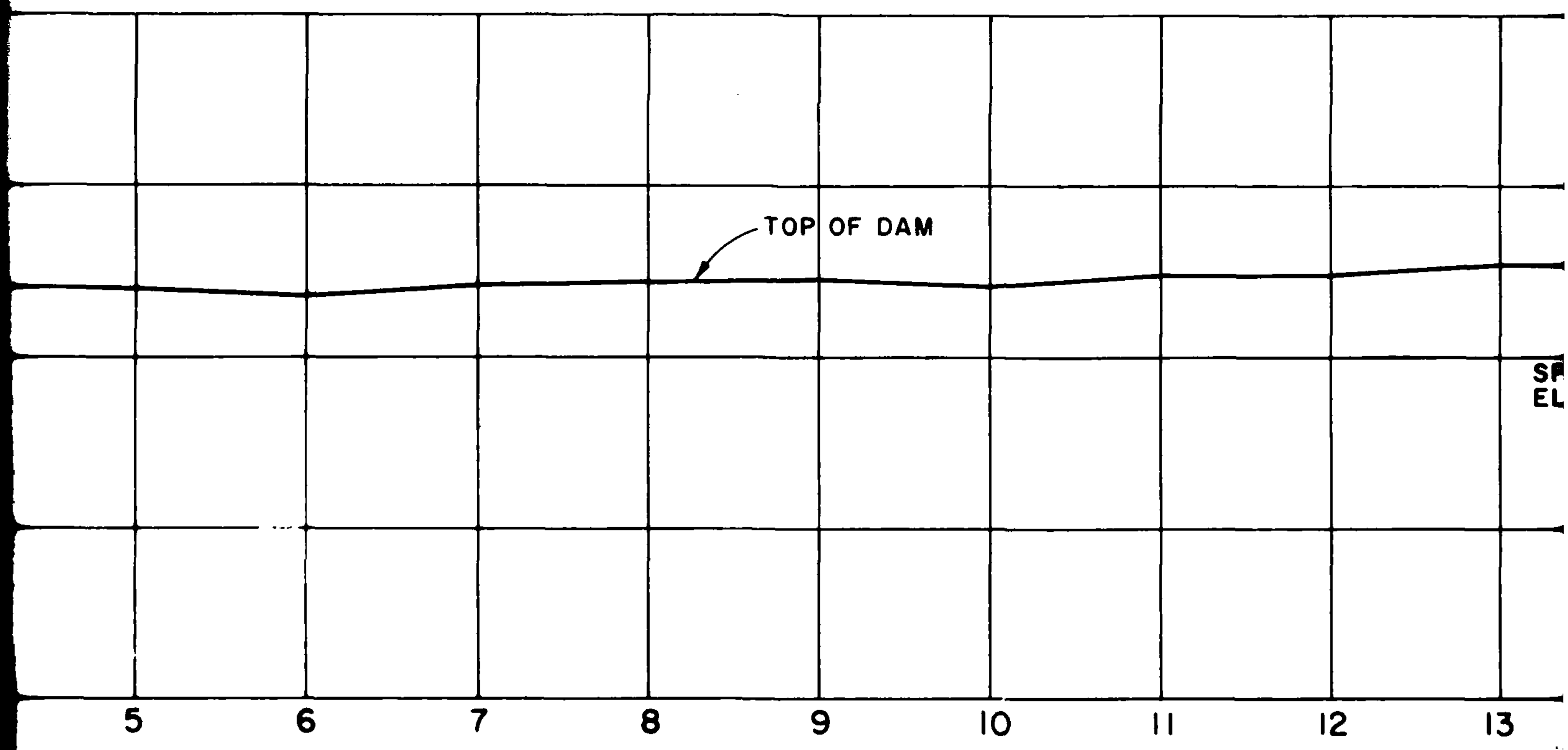
6

PHOTO LOCATION & KEY
(SEE APPENDIX A)

* FROM ROAD

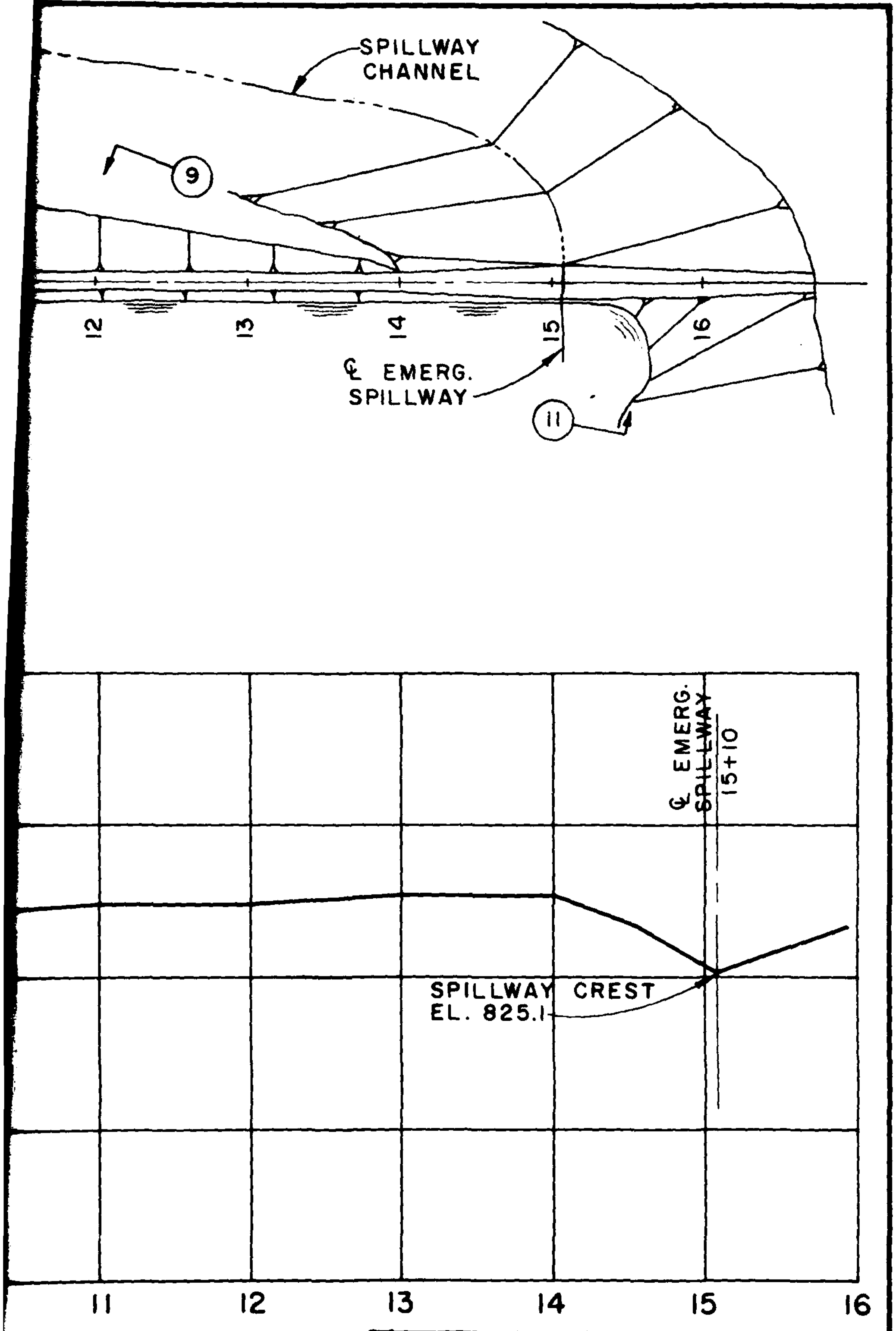


GENERAL PLAN OF DAM
SCALE: 1"=100'



PROFILE DAM CREST
SCALES 1" = 5' V., 1" = 100' H.

Horn



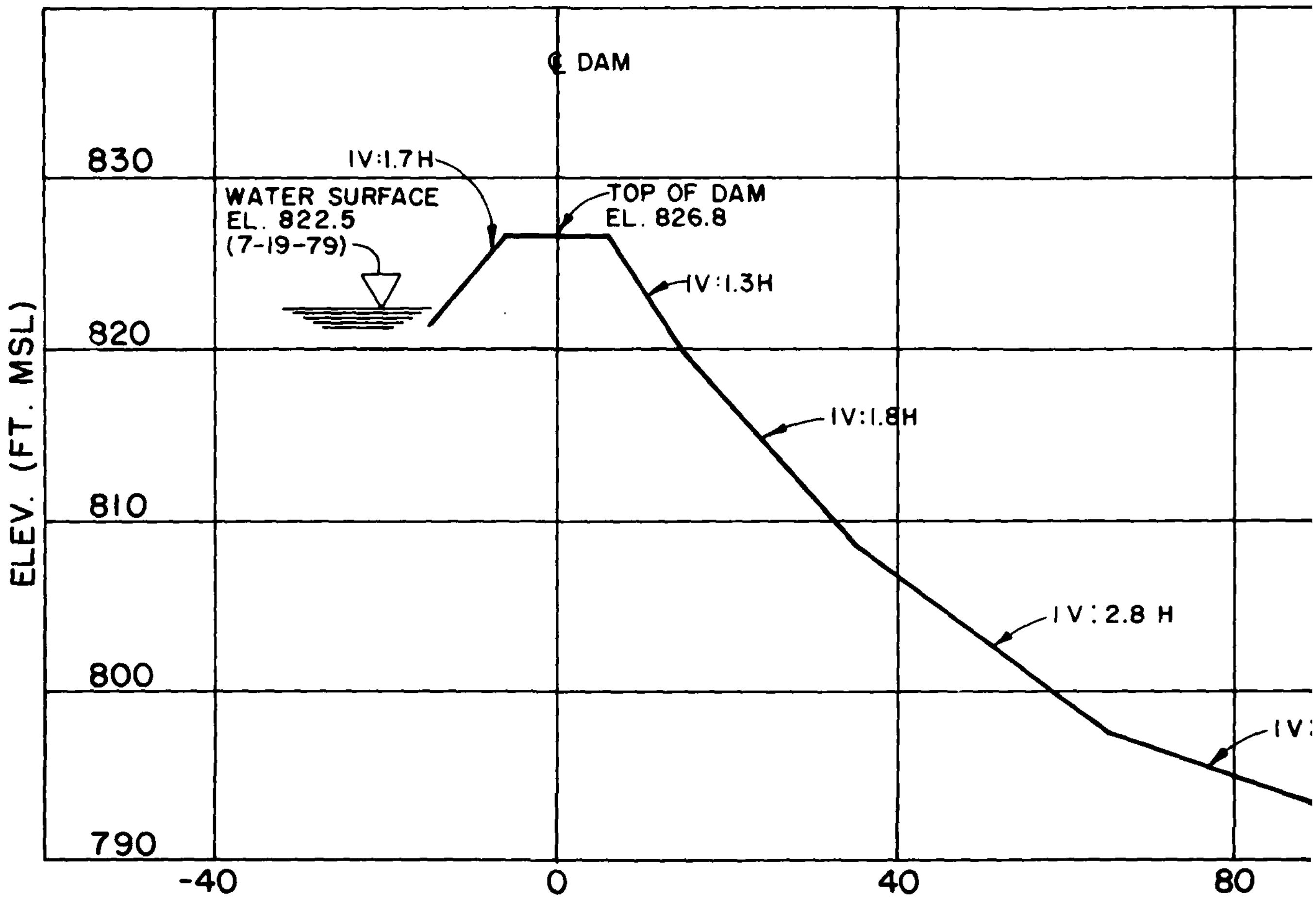
COLE LAKE

DAM PLAN & PROFILE

Horner & Shifrin, Inc. Aug. 1979

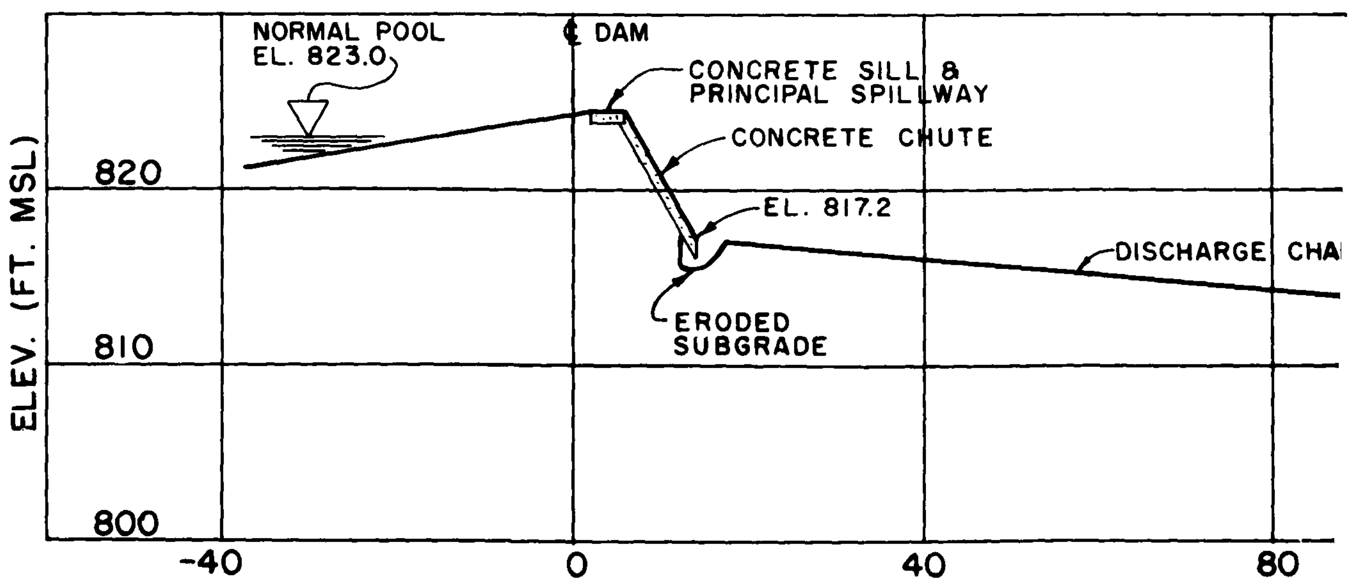
.3

PLATE 4



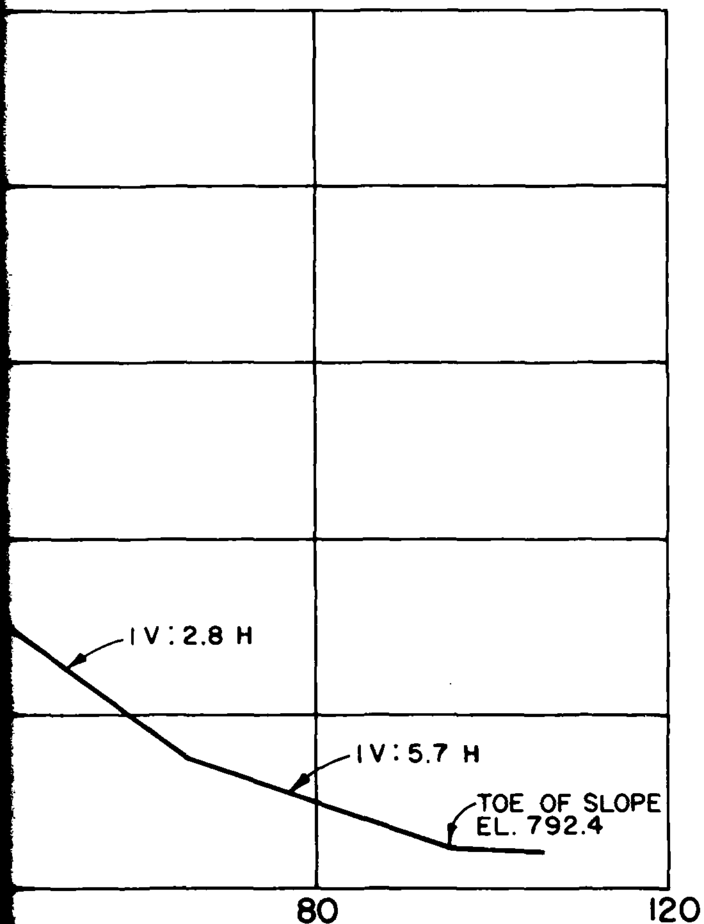
DAM CROSS SECTION STA. 6+00

SCALES 1"=10' V., 1"=20' H.



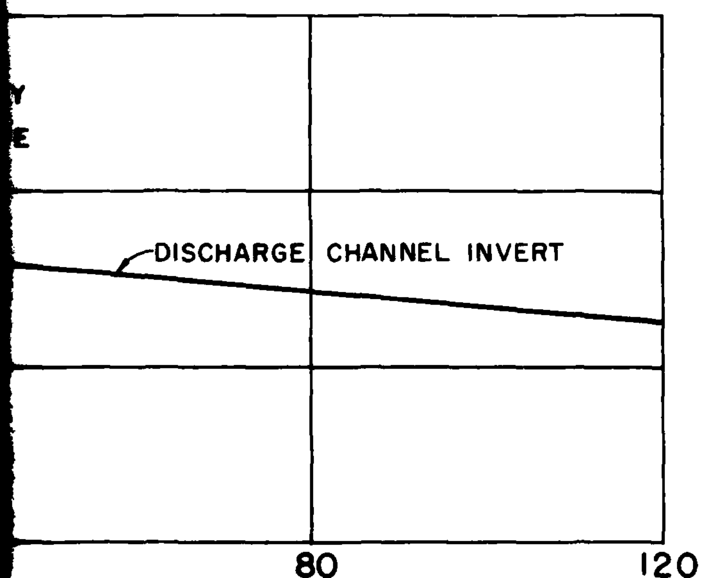
PROFILE SPILLWAY ℄

SCALES 1"=10' V., 1"=20' H.



TA. 6+00

H.



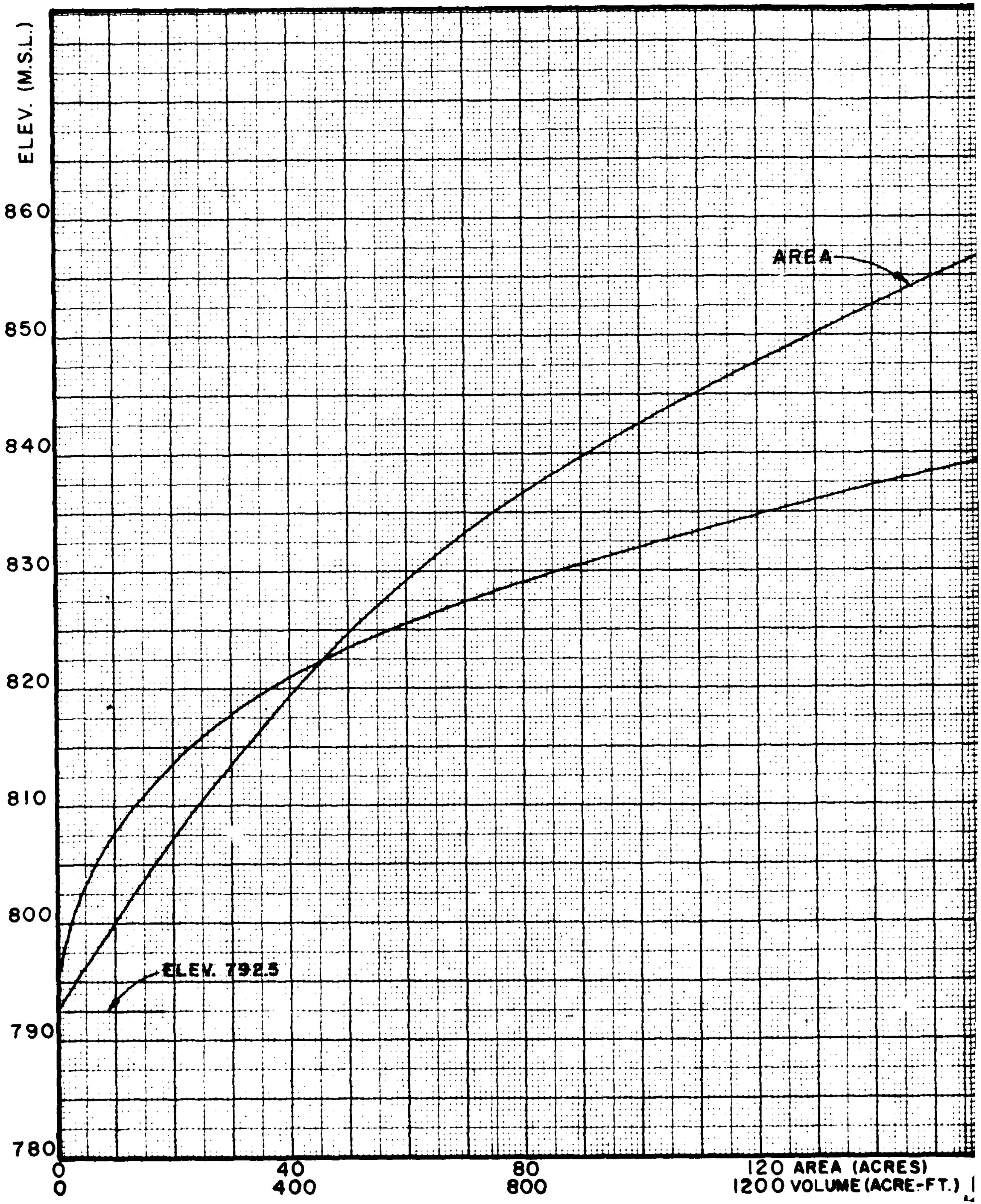
₵

H.

COLE LAKE
DAM CROSS SECTION &
SPILLWAY PROFILE

Horner & Shifrin, Inc. Aug. 1979

PLATE 5


ELEV. (M.S.L.)
860
850
840
830
820
810
800
790
780
AREA
ELEV. 792.5
0
0
40
400
80
800
120 AREA (ACRES)
1200 VOLUME (ACRE-FT.)

1

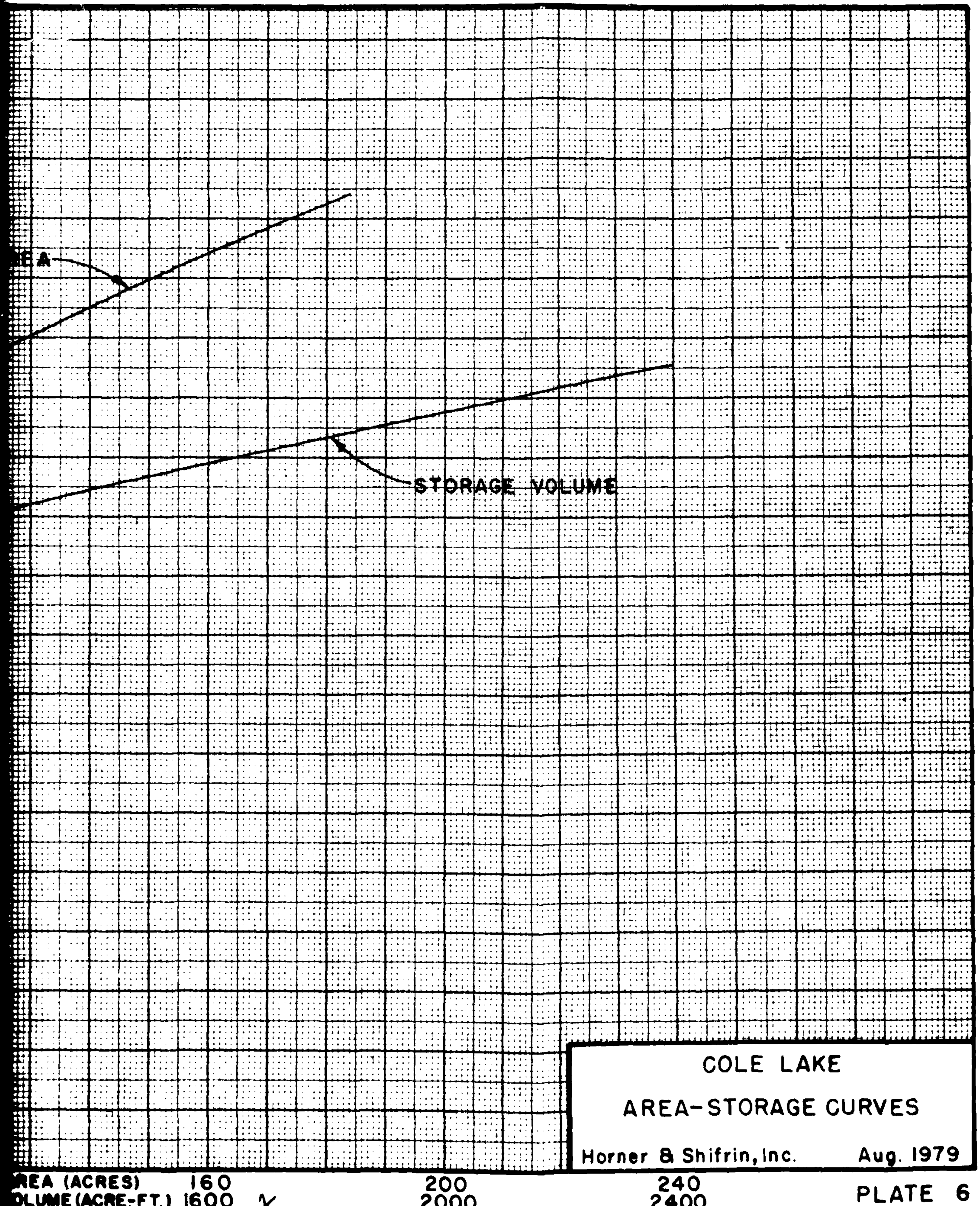
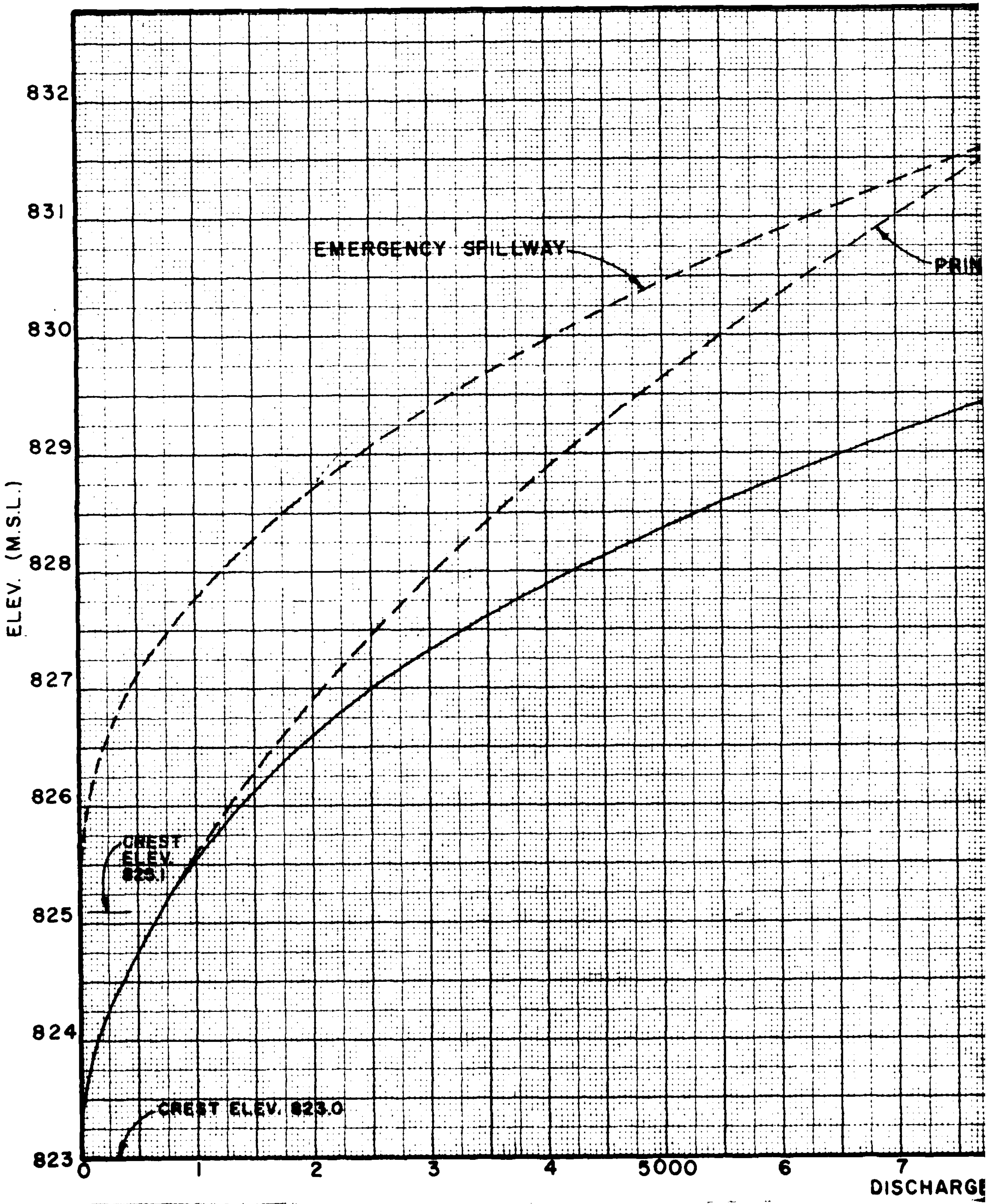
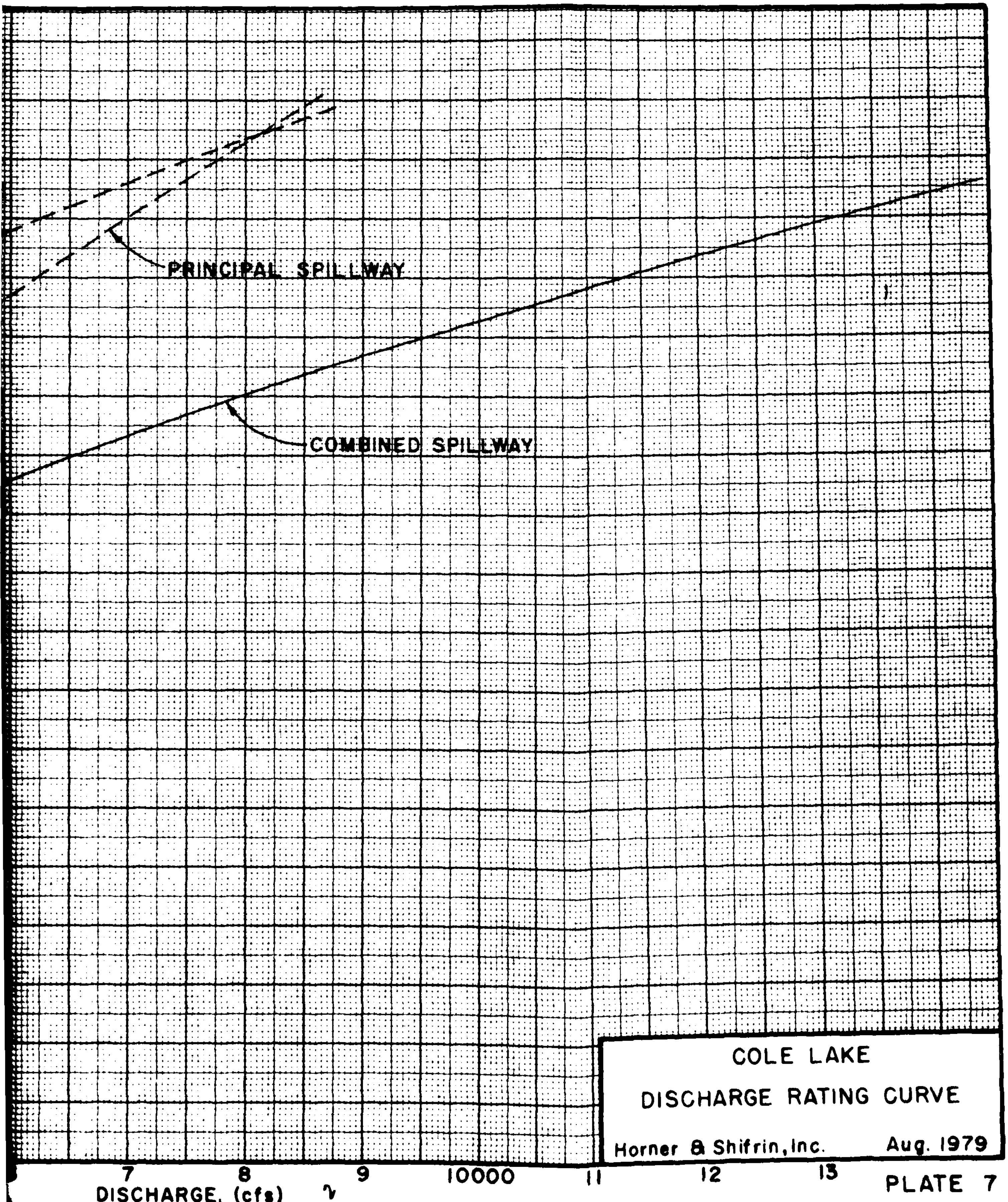

REA
STORAGE VOLUME
COLE LAKE
AREA-STORAGE CURVES
Horner & Shifrin, Inc.
Aug. 1979
REA (ACRES) 160
OLUME (ACRE-FT.) 1600
200
2000
240
2400

PLATE 6


832
831
830
829
828
827
826
825
824
823
ELEV. (M.S.L.)
EMERGENCY SPILLWAY
PRIN
CREST ELEV. 825.1
CREST ELEV. 823.0
0
1
2
3
4
5000
6
7
DISCHARGE



COLE LAKE

DISCHARGE RATING CURVE

Horner & Shifrin, Inc. Aug. 1979

PLATE 7

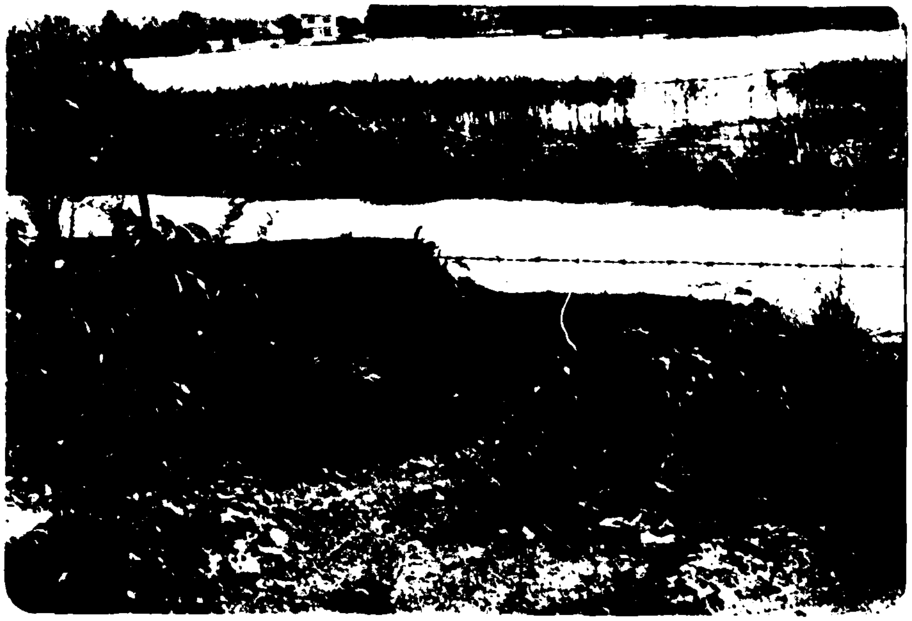
APPENDIX A

INSPECTION PHOTOGRAPHS

NO. 1: UPSTREAM FACE OF DAM

NO. 2: DOWNSTREAM FACE OF DAM

NO. 3: PRINCIPAL SPILLWAY APPROACH CHANNEL



NO. 4: PRINCIPAL SPILLWAY SILL

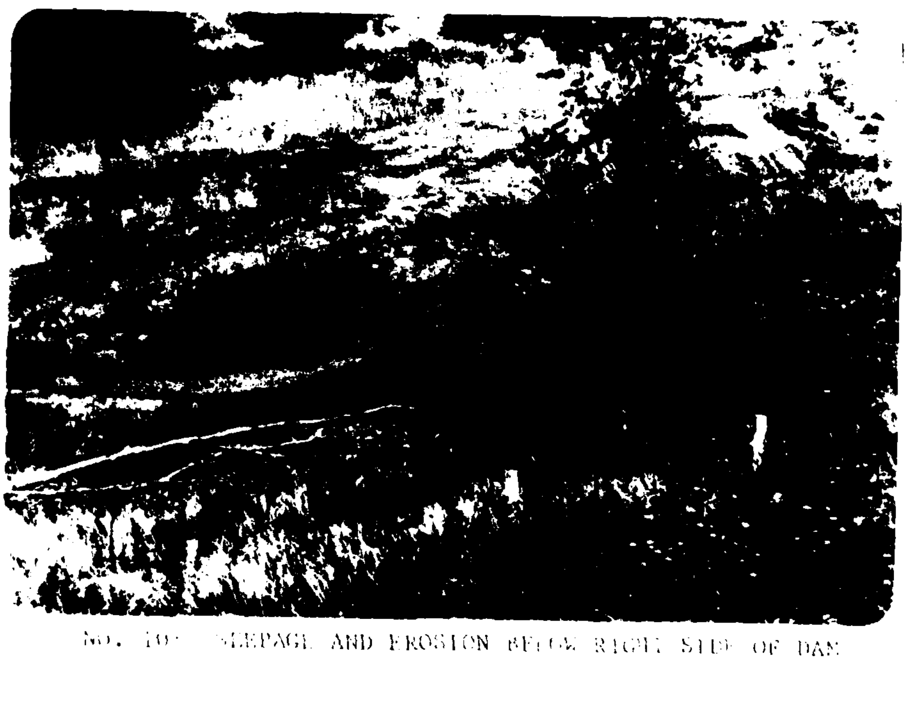
NO. 5: SPILLWAY OUTLET CHANNEL CHUTE

NO. 6: SPILLWAY OUTLET CHANNEL

NO. 7: UNPROTECTED DOWNSTREAM SLOPE

NO. 8: THROUGH SEEPAGE NEAR CENTER OF DAM

NO. 9: SEEPAGE FLOW NEAR RIGHT ABUTMENT



NO. 10: SEEPAGE AND EROSION BELOW RIGHT SIDE OF DAM

NO. [illegible] EMERGENCY SPILLWAY APPROACH CHANNEL & [illegible]

NO. 12: RIPRAP SLOPE PROTECTION

APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978, Modified 26 February 1979) program was used to develop inflow and outflow hydrographs and dam overtopping analyses, with hydrologic inputs as follows:

a. Probable maximum precipitation (200 sq. mile, 24-hour value equals 26.0 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent (100-year flood) was provided by the St. Louis District, Corps of Engineers.

b. Drainage area = 1.21 square miles = 774 acres.

c. SCS parameters:

Lag time = 0.30 hours
Soil Group C = 100 percent
Soil type CN = 75 (AMC II), 88 (AMC III)
Lag Time = 0.60 Tc (SCS Method)
Time of Concentration (Tc) = $\left(\frac{11.9L^3}{H}\right)^{0.385}$

Where; T_c = Travel time of water from hydraulically most distant point to point of interest, hours

L = Length of longest watercourse, miles

H = Elevation difference, feet.

2. The principal and emergency spillway sections consist respectively of broad-crested, trapezoidal and V-shaped sections for which conventional weir formulas do not apply.

Spillway release rates for these sections were determined as follows:

a. Spillway crest section properties (area, a and top width, t) were computed for various depths, d.

b. It was assumed that flow over the spillway crest would occur at critical depth. Flow at critical depth. Flow at critical depth was computed as $Q_c = \left(\frac{a^3 g}{t}\right)^{0.5}$ for the various depth, d. Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.

c. Static lake levels corresponding to the various values passing over the spillway were computed as critical depths plus critical velocity head ($d_c + H_{vc}$), and the relationship between lake level and spillway discharge was thus obtained. The procedure neglects the minor insignificant friction losses across the length of the spillway.

3. The profile of the dam crest between the principal spillway and emergency spillway is irregular and flow over the dam crest cannot be determined by conventional weir formulas. Crest length and elevation data for the dam crest proper were entered into the HEC-1 Program on the $L and the $V cards. The program computes internally the flow over the dam crest and adds this flow to the flow over the principal and emergency spillways as entered on the Y4 and Y5 cards.

```
A1      ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2      HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF COLE LAKE DAM
A3      RATIOS OF PMF ROUTED THROUGH RESERVOIR
B      288       0       5                                               0
B1       5
J        1       8       1
J1     .25     .26     .27     .28     .29     .30     .50     1.0
K        0  INFLOW                                       1
K1      INFLOW HYDROGRAPH
M        1       2    1.21                     1.0                       1
P        0    26.0     102     120     130
T                                                       -1     -88
W2            0.30
X     -1.0    -.10     2.0
K        1     DAM                                       1
K1      RESERVOIR ROUTING BY MODIFIED PULS
Y                                1       1
Y1       1                                           475.8      -1
Y4   823.0   823.5   824.0   824.5   825.1   825.5   826.0   826.5   827.0   827.5
Y4   828.0   828.5   829.0   829.5   830.0   830.5   831.0   831.5
Y5       0      40     150     370     690     960    1380    1880    2520    3300
Y5    4250    5300    6530    7960    9560   11300   13220   15270
$A       0    46.8    90.9   174.5
$E   792.5   823.0   840.0   860.0
$$   823.0
$D   826.4
$L       1     140     354     470     677    1061    1098    1234    1318    1418
$V   826.4   826.6   826.9   827.0   827.1   827.3   827.4   827.5   827.7   827.8
K       99
```

```
A1        ANALYSIS OF DAM OVERTOPPING USING 100YR FLOOD
A2        HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF COLE LAKE DAM
A3        100YR FLOOD ROUTED THROUGH RESERVOIR
B     288        0       5                                                  0
B1      5
J       1        1       1
J1    1.0      .10     .15     .20     .25     .30    0.40     .50    1.00
K       0  INFLOW                                        1
K1        INFLOW HYDROGRAPH
M       0        2    1.21                     1.0                         1
O     288
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .013    .013    .013    .013    .013    .013
O1   .013     .013    .013    .013    .024    .024    .024    .024    .024    .024
O1   .024     .024    .024    .024    .024    .024    .024    .024    .024    .024
O1   .024     .024    .031    .031    .031    .031    .031    .031    .049    .049
O1   .049     .049    .049    .049    .138    .139    .139    .262    .262    .544
O1   .313     .378    .262    .139    .139    .138    .049    .049    .049    .049
O1   .049     .049    .031    .031    .031    .031    .031    .031    .024    .024
O1   .024     .024    .024    .024    .024    .024    .024    .024    .024    .024
O1   .024     .024    .024    .024    .024    .024    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007     .007    .007    .007    .007    .007    .007    .007
T                                                        -1     -75
W2           0.30
X    -1.0     -.10     2.0
K       1      DAM                                        1
K1        RESERVOIR ROUTING BY MODIFIED PULS
Y                                 1       1
Y1      1                                              475.8      -1
Y4  823.0    823.5   824.0   824.5   825.1   825.5   826.0   826.5   827.0   827.5
Y4  828.0    828.5   829.0   829.5   830.0   830.5   831.0   831.5
Y5      0       40     150     370     690     960    1380    1980    2520    3300
Y5   4250     5300    6530    7960    9560   11300   13220   15270
$A      0     46.8    90.9   174.5
$E  792.5    823.0   840.0   860.0
$S  823.0
$D  826.4
$L      1      140     354     470     677    1061    1098    1234    1318    1418
$V  826.4    826.6   826.9   827.0   827.1   827.3   827.4   827.5   827.7   827.8
```

RATIO OF PMF

SUMMARY OF DAM SAFETY ANALYSIS

....	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	823.00	823.00	826.40
STORAGE	476.	476.	648.
OUTFLOW	0.	0.	1780.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.25	826.20	0.00	637.	1564.	0.00	16.17	0.00
.26	826.28	0.00	642.	1665.	0.00	16.17	0.00
.27	826.36	0.00	646.	1744.	0.00	16.17	0.00
.28	826.44	.04	650.	1821.	.25	16.17	0.00
.29	826.52	.12	654.	1906.	.33	16.17	0.00
.30	826.59	.19	658.	2005.	.50	16.17	0.00
.50	827.49	1.09	709.	4668.	1.58	16.00	0.00
1.00	828.33	1.93	757.	11043.	5.00	15.92	0.00

100 YR. FLOOD

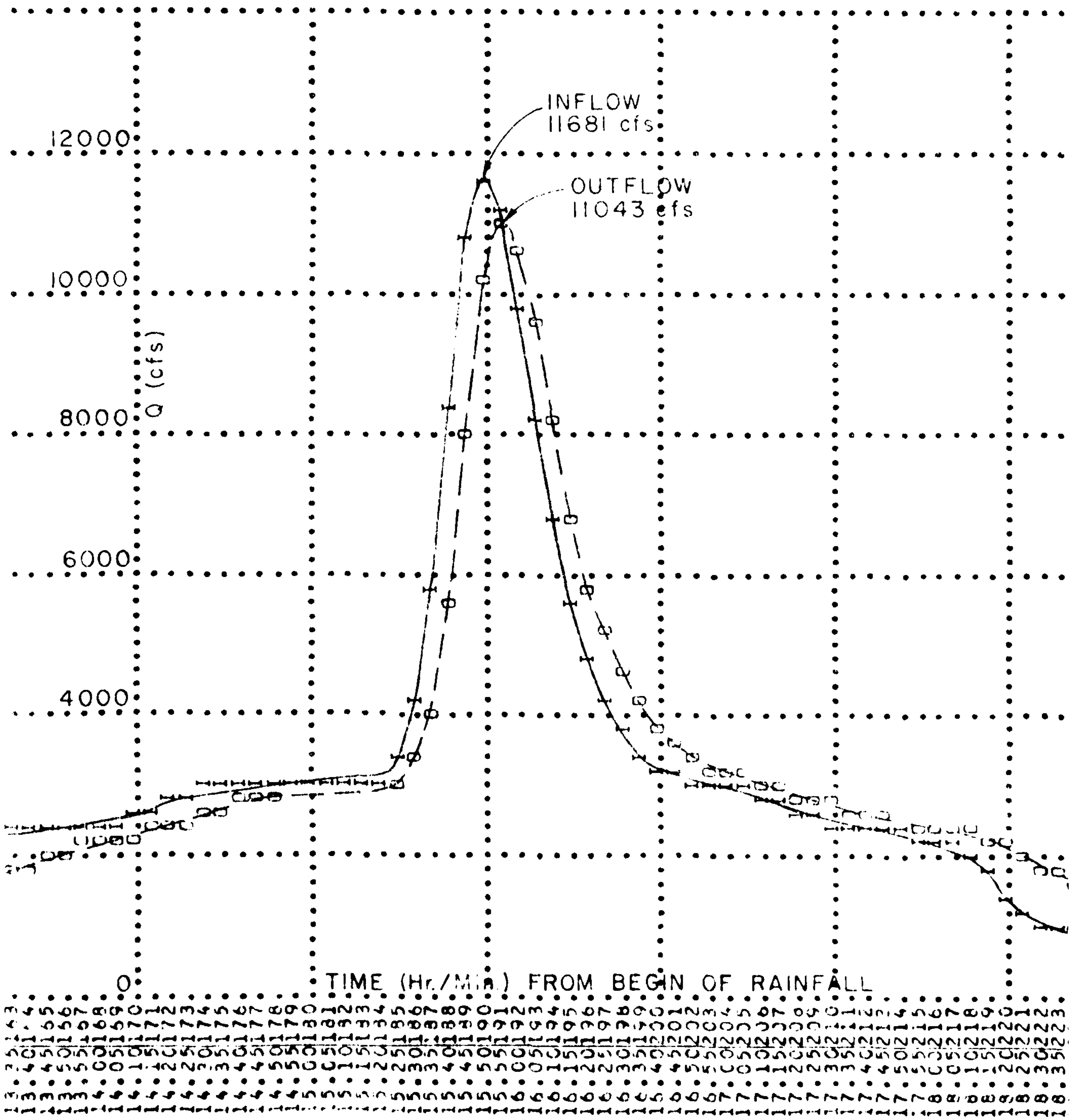
SUMMARY OF DAM SAFETY ANALYSIS

....	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	823.00	823.00	826.40
STORAGE	476.	476.	648.
OUTFLOW	0.	0.	1780.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	825.62	0.00	606.	1065.	0.00	15.83	0.00

COLE LAKE
PMF INFLOW & OUTFLOW
HYDROGRAPHS

Horner & Shifrin, Inc. Aug. 1979



DATE
ILME